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NEUTRINO BEAMS AT NAL

L. Hyman
Argonne National Laboratory

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We have investigated several aspects of ν-detector setups at NAL. For purposes of calculation, the 12-ft chamber is taken as a rectangular cross section 1.65 m by 3 m with a 3-m length.

The 25-ft chamber is taken as a cylinder 3.3 m in diameter and 6-m long.

In the wide-band system pions and kaons are focused over a large momentum band and decay in a drift space between the target and chamber. We define an ideal focus case as follows: all pions produced with $\theta \leq \theta_{max}$ are made parallel and are contained in a bundle with spatial dimensions small compared to the chamber dimensions.

For meson yields from the target we shall assume the CKP production formula

$$\frac{d^2N}{dp\,d\Omega} = \frac{Ap^2}{p_o^{1/2}} e^{-p/Bp_o^{3/4}} e^{-p\theta/C} \quad \text{(p in GeV/c)},$$

where A = 10, B = C = 0.22. The bubble chamber is at $\theta = 0$ relative to the target and $\theta_{max} = 0.0875$ rads. The choice of θ_{max} makes little difference in the range $p_\pi \gtrsim 0.44/\theta_{max}$ since $\theta_{rms} = 0.44/p$ rads.

We have chosen a shielding distance of 150 m. In Fig. 1, we have plotted the total number of neutrinos per interacting proton striking the two detectors as a function of drift distance. We assume the K yield to be 1/10 the π yield. In Fig. 1 the total flux of ν's per interacting proton is shown as a function of the drift distance. The maximum occurs at about 400 to 500 meters. We have made similar computations using the Trilling production formula (for H_2) and find small changes in the optimum drift distance. Figure 2 shows the ν spectrum at 400 m for the two chambers. Taking the 12-ft chamber with drift space of 400 m as standard in Fig. 3 we illustrate a variety of situations. These curves illustrate that experiments with a given detector may want to vary conditions. Thus, an experiment designed to study $6.0 \leq E_\nu \leq 22$ may want to harden the spectrum by increasing the drift space even if the overall flux is down. In the 12-ft bubble chamber with E_ν in the range $\geq$ 20-25 GeV K neutrinos overtake π neutrinos and the drift space may be shortened to optimize this region.

Several other factors should be considered in siting neutrino facilities:

1. A large bubble chamber used for ν physics is the same detector which would be used for a high muon (~ 100 GeV) rf separated, such a beam as described by J. Lach requires a target to detect length of ~ 1000 to 1200 m.

2. The ability to harden or soften the neutrino spectrum to optimize the physics run makes the choice of drift space an attractive feature. M. Block, for example, has emphasized that ν-$\bar{\nu}$ differences are

best looked for in the neutrino momentum range ~ 500 MeV/c. Using CKP a 25-GeV beam produces 50% more 2-BeV pions than a 200-GeV proton beam. To utilize this, one must have external beam magnets which track the machine or run the machine at less than full energy (which increases the rep rate).

3. It is possible that the machine energy may be increased to 400 GeV within relatively short time after initial operating conditions are obtained. At 400 GeV the optimum drift space moves out to between 600 and 800 m.

This all appears to add up to a system with a reasonably flexible target to detector distance. The maximum required distance is ~ 1000 to 1200 m. It has been proposed that the proton beam be extracted 25 ft below grade and aimed up a slightly tilted tunnel toward a detector ~ 1000 m away at grade.

We have tried an ideal plasma lens tuned at various momenta and while the spectral shape shifts with the tune, the total rate compared to the ideal rate is relatively insensitive to the lens tune. The efficiency is ~ 25-30% of ideal.

We have checked the narrow band system using $p = 20$ GeV/c $\Delta p/p = 0.10$ (FWHM) and $\theta_{max} = \theta_{rms} = 0.44/p$. We find using CKP that the narrow band system is ~ 0.08 × ideal rate. It appears unlikely that such a beam would be used for the first round of experiments at NAL.

Some additional points which require study are

1. conclusions using Hagedorn-Ranft production data,

2. beam design with real-life focusing devices,

3. estimate of problems associated with μ (produced by ν in the rear end of shielding) which then strike the detector, also neutron background,

4. detectors other than bubble chambers,

5. type and size of shielding,

6. $\bar{\nu}/\nu$ ratio when running ν,

7. plans for beam survey relevant to ν needs, and instrumentation and equipment to check muon spectrum for example.

ν Rates in 12 ft and 25-ft Chamber

For the 25-ft chamber we assume a diameter of 3.3 m and a length of 6 m. We use deuterium with $\rho = 0.12$ g/cm^3 and total cross section of 2×10^{-38}cm^2. Using 0.12 ν/interacting proton and a targeting efficiency of 1/3 we find 0.18 events/10^{13} circulating protons. Using a rectangular cross section of 1.65×3 m for the fiducial area of the 12 ft and 3-m length, the rate is down by a factor of ~ 3. For $E_\nu \geq 8$ GeV this factor is more nearly 2.4. The fiducial volumes have not been studied in detail for camera coverage analyzability of event, etc.

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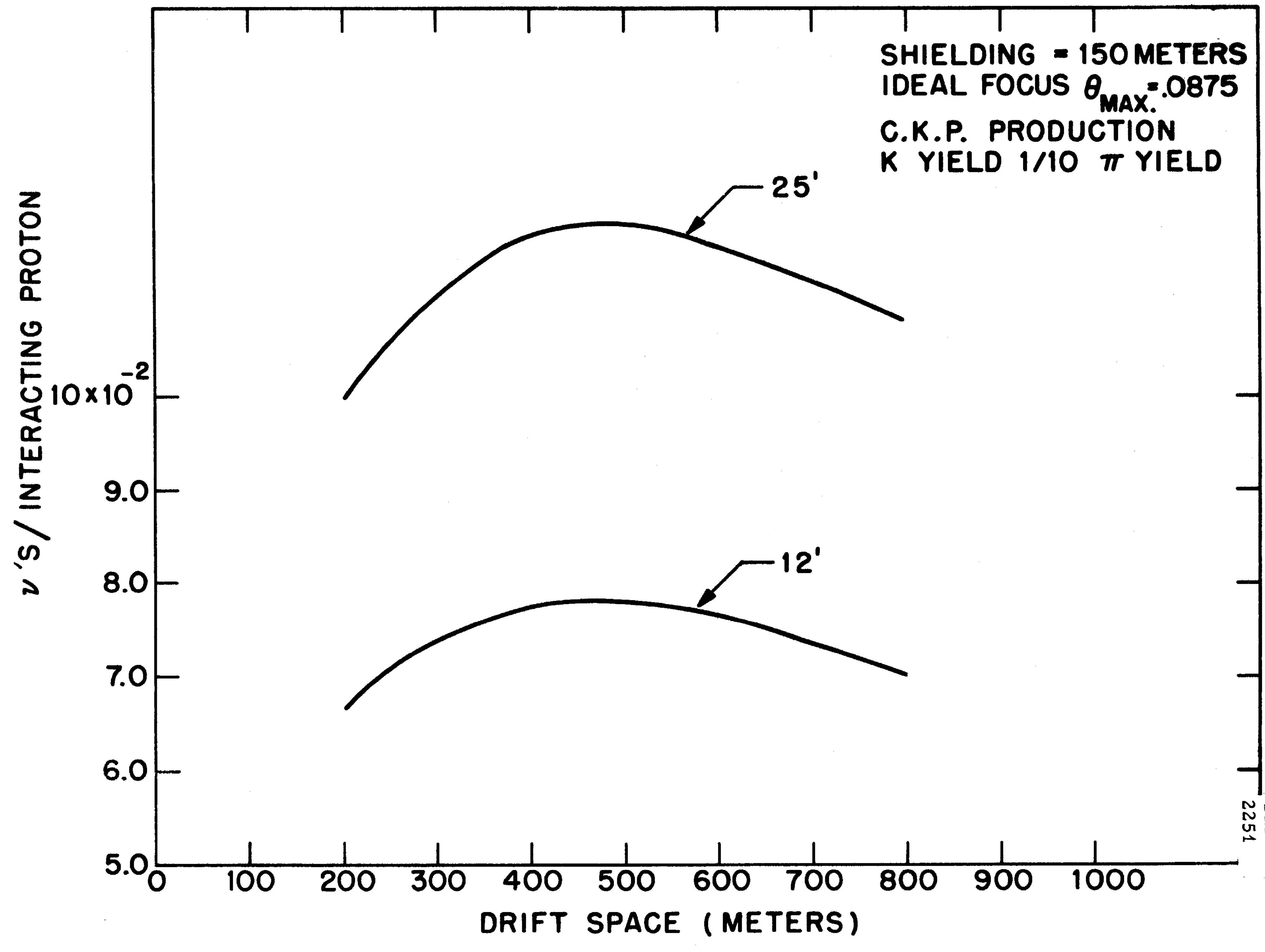
SHIELDING = 150 METERS
IDEAL FOCUS $\theta_{MAX.}$ = .0875
C.K.P. PRODUCTION
K YIELD 1/10 π YIELD
25'
12'
10×10^{-2}
9.0
8.0
7.0
6.0
5.0
0
100
200
300
400
500
600
700
800
900
1000
ν'S / INTERACTING PROTON
DRIFT SPACE (METERS)

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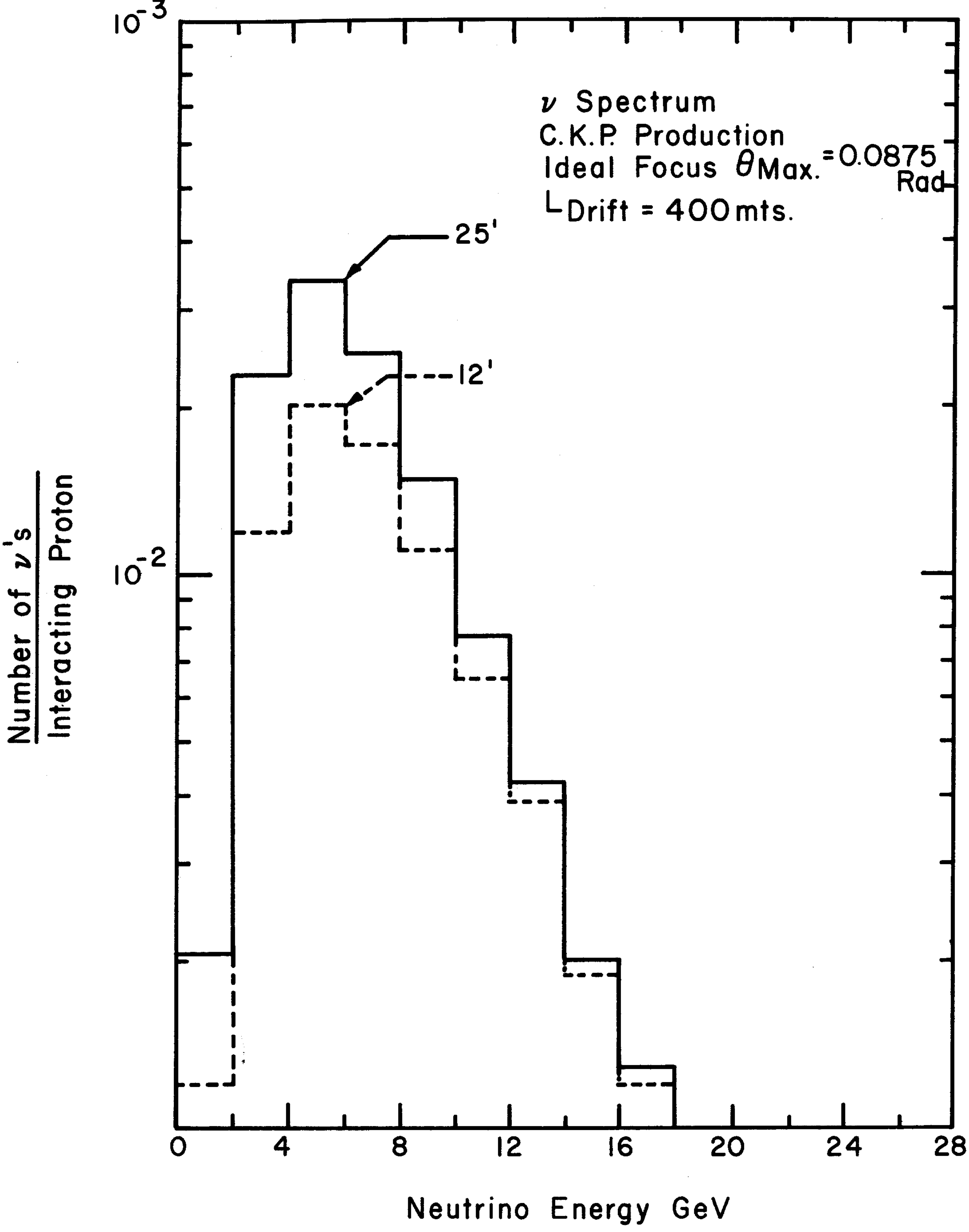

Fig. 2. Neutrino spectrum for ideal focusing, 400 meter drift distance.

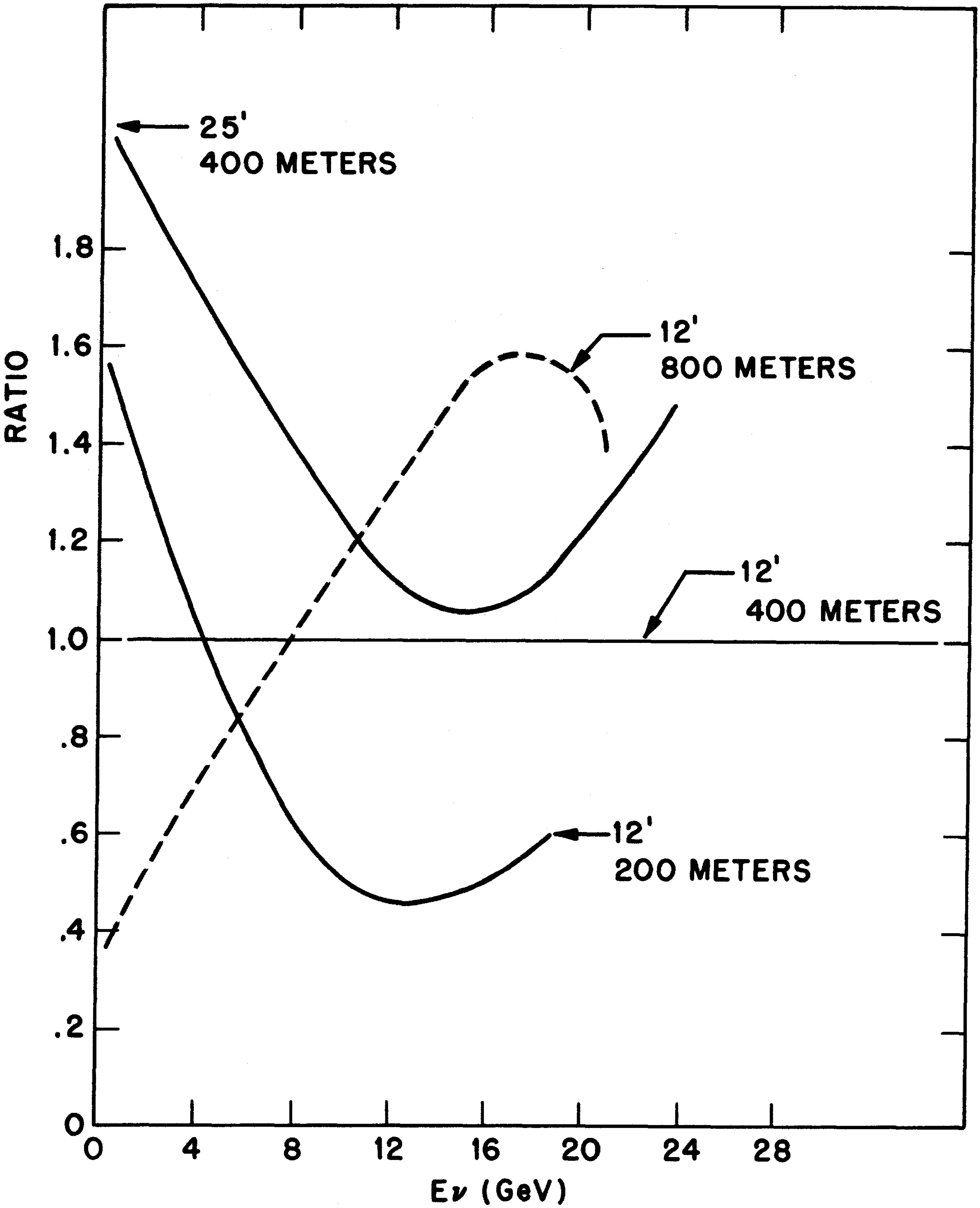

Fig. 3. Correction factor to spectrum of Fig. 2, for a variety of